(12) UK Patent Application (19) GB (11) 2 258 899 (13) A

(43) Date of A publication 24.02.1993

(21) Application No 9217004.2

(22) Date of filing 11.08.1992

(30) Priority data
(31) 9117958 (32) 20.08.1991 (33) GB

(71) Applicant
United Kingdom Atomic Energy Authority

(Incorporated in the United Kingdom)

Harwell Laboratory, Didcot, Oxfordshire, OX11 0RA, United Kingdom

(72) Inventor
Alexander Edwin Bond

(74) Agent and/or Address for Service
Peter Turquand Mansfield
United Kingdom Atomic Energy Authority, Patents Department, Building 329, Harwell Laboratory, Oxfordshire, OX11 0RA, United Kingdom

(51) INT CL[5]
F16L 13/00, F16C 3/02

(52) UK CL (Edition L)
F2G GRX G18 G18E G24E G24E2 G24E5 G33
F2U U13E
U1S S1248

(56) Documents cited
GB 2112689 A GB 2051303 A GB 1405139 A
GB 0718264 A GB 0291674 A GB 0254619 A
GB 0248130 A WO 88/01887 A1

(58) Field of search
UK CL (Edition K) F2G GRX G18 G24E G24Z G33, F2U
INT CL[5] F16C 3/02, F16L

# (54) A joint

(57) A joint for a drillstring pipe or driveshaft comprises a tube (11) of a fibre reinforced composite plastic material with a frusto-conical end portion (13) which is mechanically interlocked to an annular end-fitting (15) with frusto-conical surfaces (20, 21) which mate with the inner and outer surfaces of the frusto-conical end portion of the tube. The joint is assembled whilst the composite tube is in the green state and on assembly the frusto-conical surfaces (20, 21) may be adhesively bonded to the frusto-conical surfaces of the frusto-conical end portion (13).

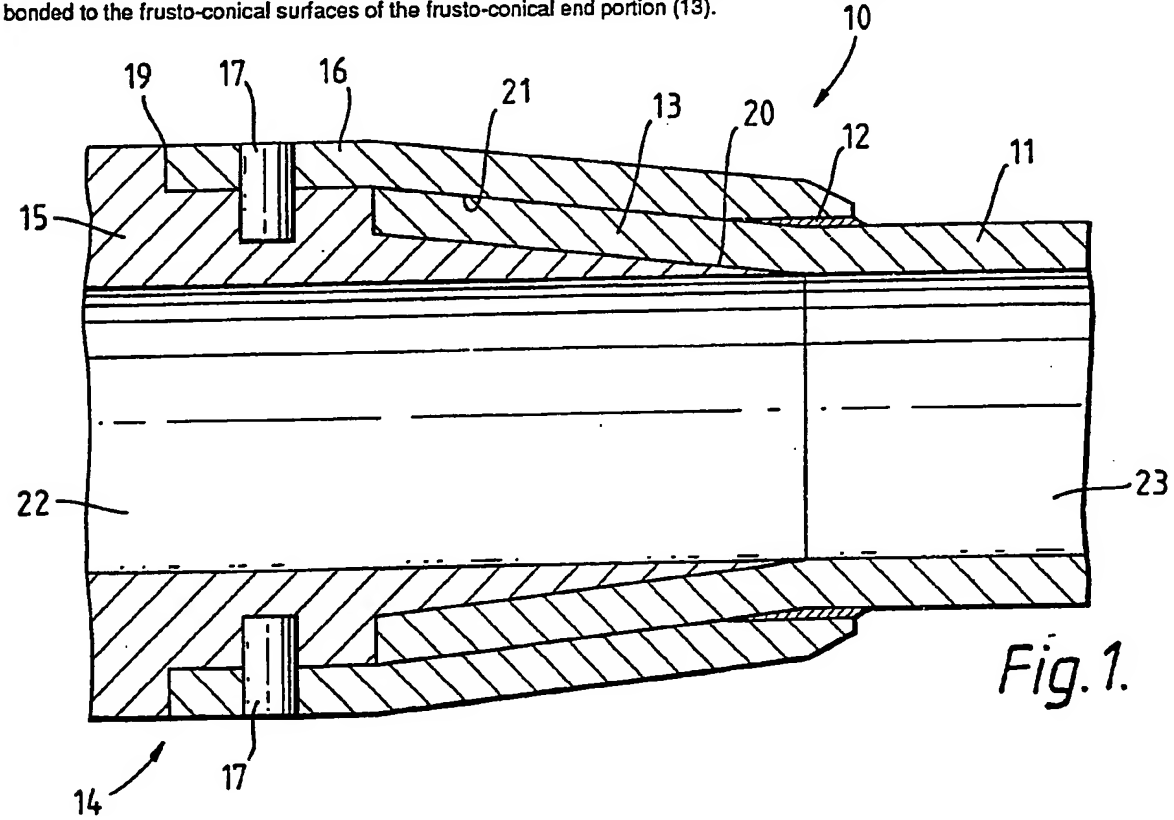



Fig. 1.

GB 2 258 899 A

Fig. 1.

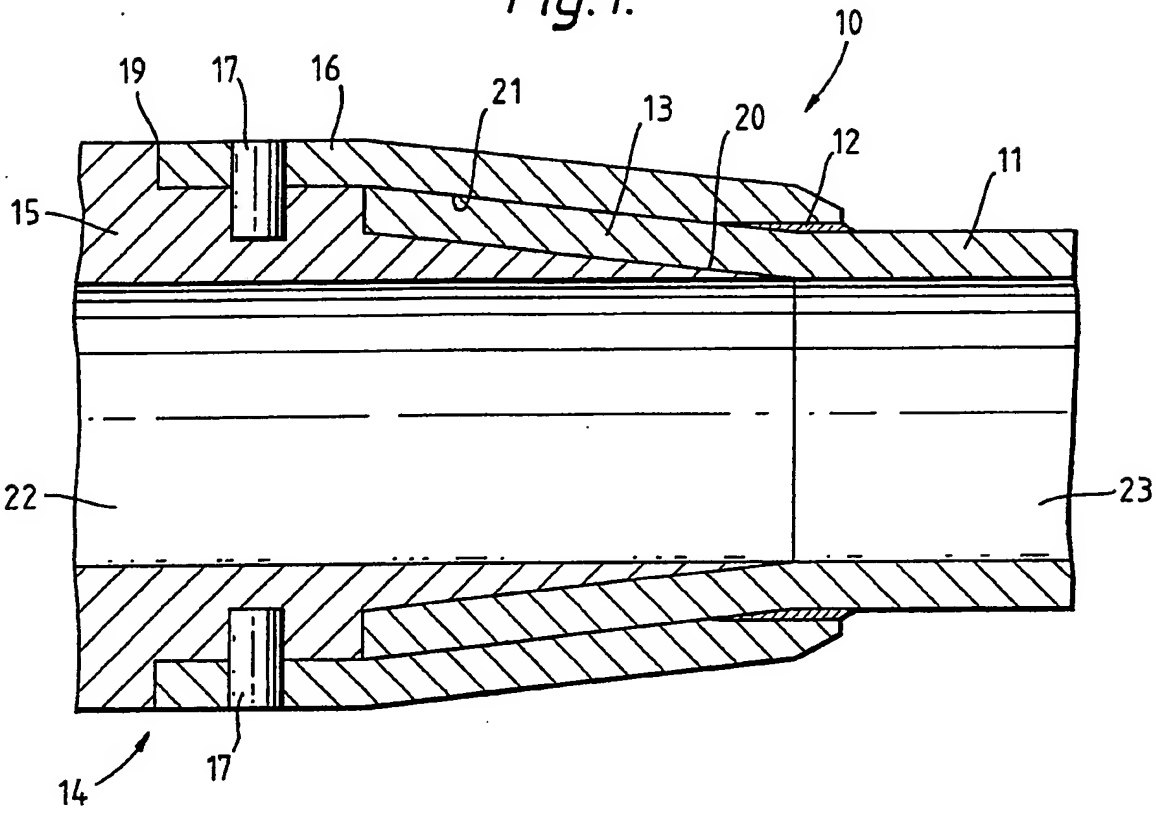



Fig. 4.

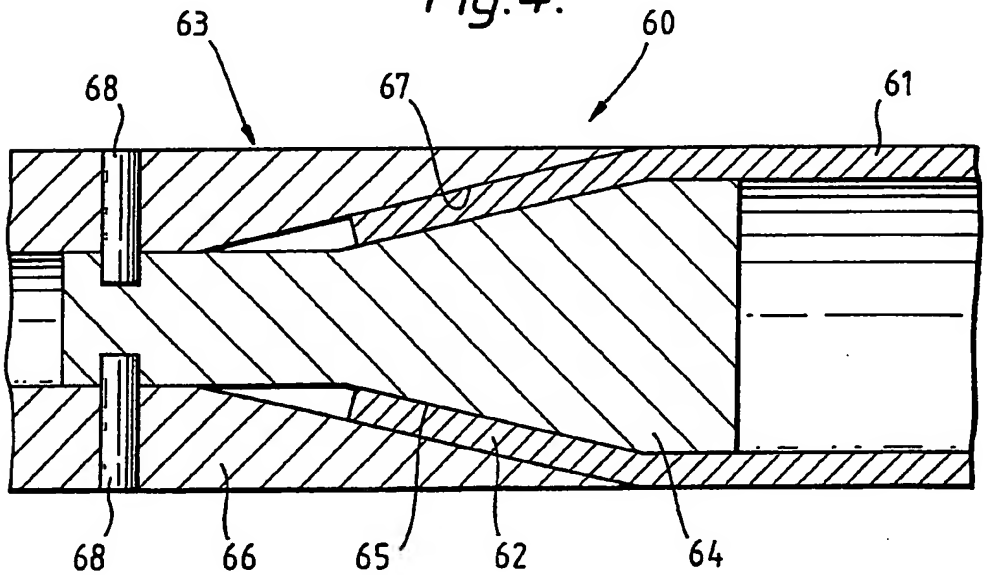


Fig.2.

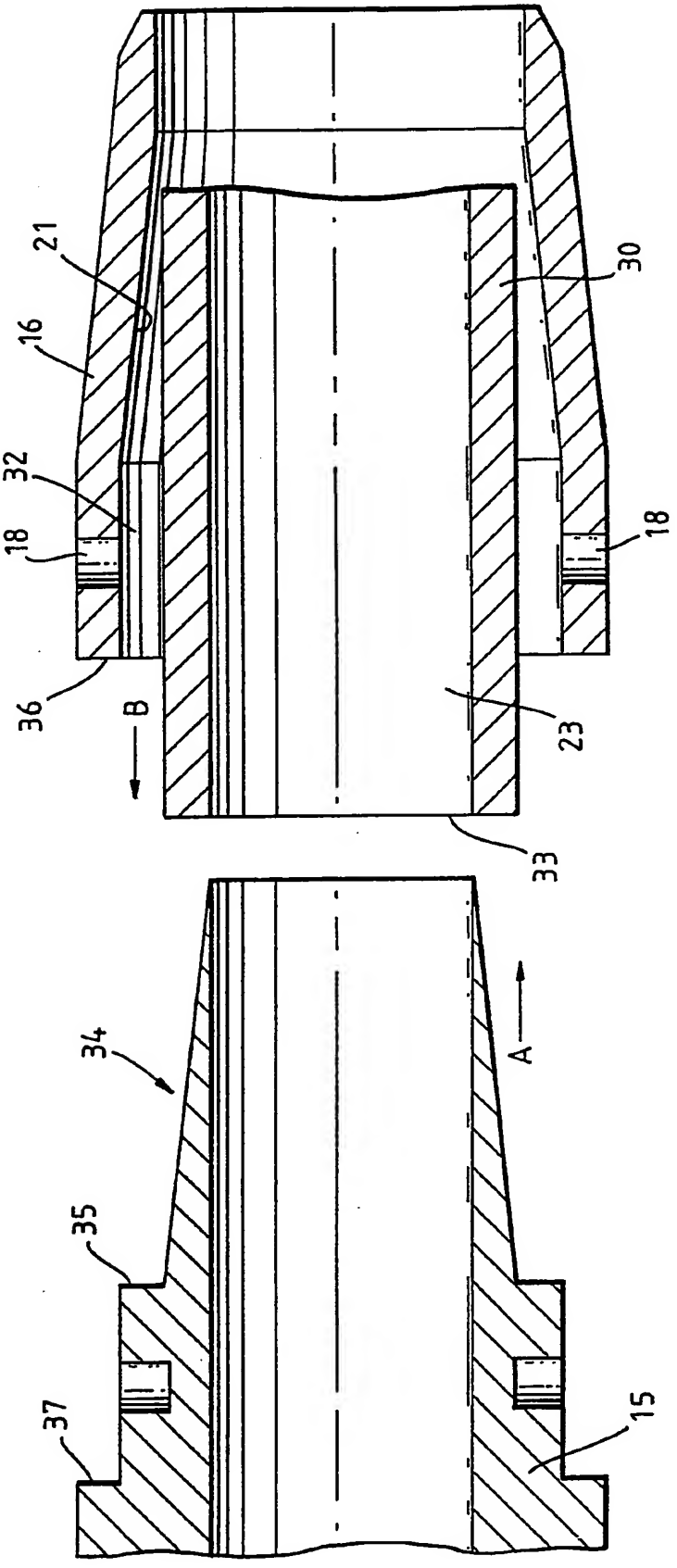
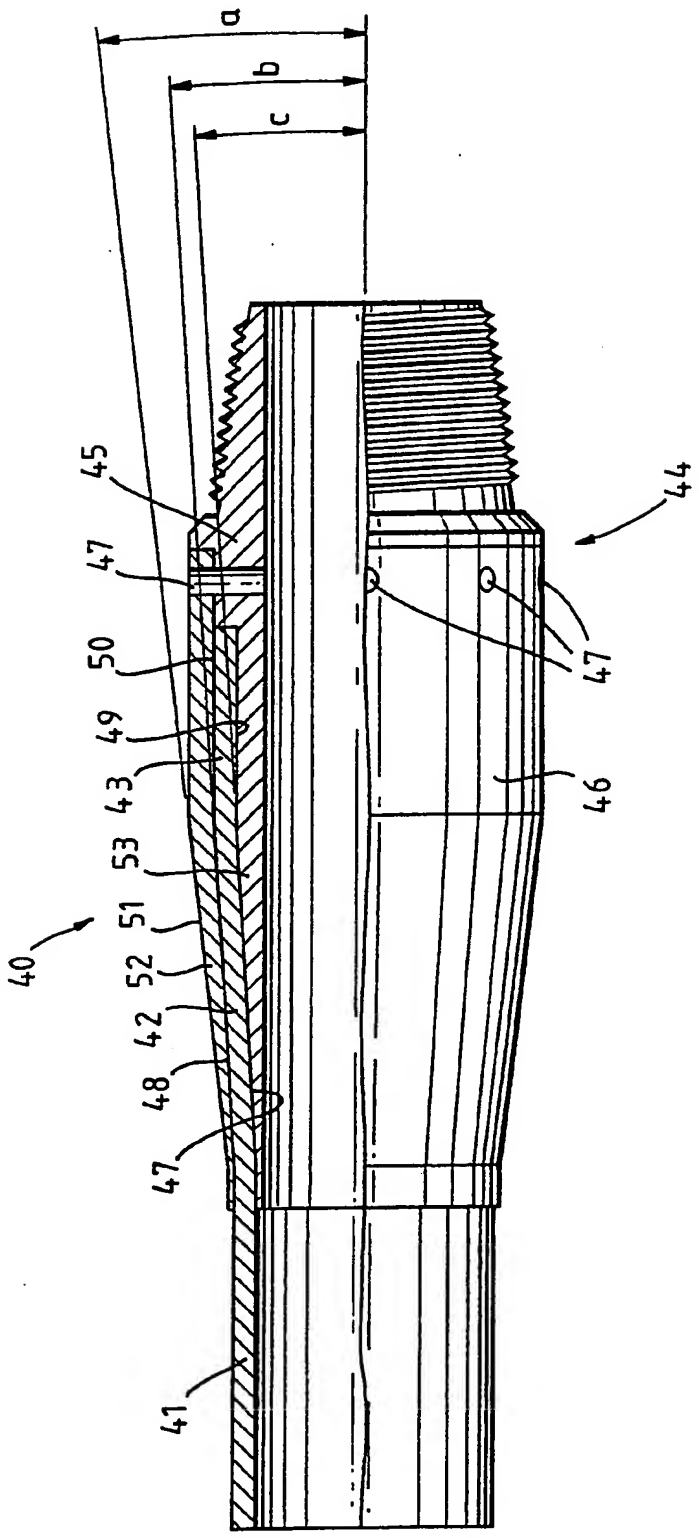


Fig. 3.



# A Joint

This invention relates to a joint and more especially to a joint between a shaft of a fibre reinforced composite material and an end-fitting assembly which may be of a different material, for example of metal; and to a method of manufacture of such a joint.

According to the present invention there is provided a joint which comprises a shaft of a fibre reinforced plastic material with a frusto-conical tubular end-portion, with cone half-angle of less than 45° with respect to the joint axis, axially interlocked with an end-fitting assembly which comprises an inner member with an outward facing frusto-conical surface and an annular one-piece outer member with an inward facing frusto-conical surface, the said frusto-conical surfaces of the inner and the outer members mating with inner and outer frusto-conical surfaces of the frusto-conical end portion of the shaft, and the inner and the outer members being secured to each other.

The present invention also provides a method of manufacture of a joint, the method comprising inserting an inner member defining an outward facing frusto-conical surface into an end of a shaft of a fibre reinforced plastic material in its green state, such that a frusto-conical tubular end portion is formed in the shaft pushing an annular outer member defining an inward facing frusto-conical surface along the outside of the shaft toward the frusto-conical end portion until its frusto-conical surface mates with the external surface of the frusto-conical end portion, securing the annular outer member to the inner member to form an end-fitting assembly, and treating the end-fitting assembly to convert the composite shaft from its green state to its cured state.

It is preferred that the frusto-conical end portion is imperforate. However if the cross-sectional thickness of the composite tube walls is large additional bolting through the frusto-conical end portion may be necessary.

It is preferred that the frusto-conical surfaces of the end portion and frusto-conical surfaces of the inner and annular outer members of the joint are adhesively bonded. It is also preferred that the adhesive used for bonding is cured when the composite shaft is cured. When used the adhesive may be applied to either the frusto-conical surfaces of the inner and annular outer members or to the end of the composite tube which forms the frusto-conical end portion prior to the assembly of the composite joint, or preferably to both. The adhesive may spill out of the joint or assembly to form a fillet which may improve the strength of the joint. The adhesive may be any suitable adhesive, for example an epoxy adhesive or a phenolic nitrile adhesive. It is preferred that the adhesive is chemically similar to or compatable with the plastic material of the composite tube.

Alternatively the adhesive may be a layer region of the frusto-conical end-portion of the composite tube which has reduced fibre reinforcement or no fibre reinforcement at the surfaces to be bonded; the excess plastic which is not reinforced or with reduced reinforcement acts as an integral adhesive, that is to say an adhesive layer which is integral with the composite tube. Alternatively additional plastic material may be added to the composite tube, in a region of the composite tube which forms a frusto-conical end-portion, during manufacture of the composite tube: this would leave excess plastic at the tube surface in the region of the frusto-conical end-portion to act as an integral adhesive.

The frusto-conical surfaces of the inner and the outer members may be of circular cross-section, that is to say as derived from a cone of circular base. They might alternatively include one or more plane inclined surfaces, or indeed might be of triangular or polygonal cross-section as derived from a pyramid of triangular or polygonal base. They might also or alternatively define grooves or ridges.

The composite shaft may be of any desired cross-sectional shape, such as circular, triangular or polygonal, and may if desired be tubular. When the composite shaft is tubular the internal bore of the shaft may have the same or different cross-section to that of the shaft itself.

The end-portion may have a wall thickness which increases in thickness towards the end of the composite tube. The frusto-conical inner and outer surfaces of the frusto-conical end portion may have different cone half-angles with respect to the composite tube axis; thus they would no longer be substantially parallel and would therefore define a wedge shaped frusto-conical end-portion. The wedge shaped end-portion adds the additional feature of wedge inter-locking of the composite tube with the end-fitting.

The composite shaft may be made of any suitable fibre or filament reinforced plastic material for example fibre reinforced epoxy resins, and may be manufactured by any suitable means. For example when the shaft is not tubular it may be manufactured by pultrusion. When the shaft is tubular it may be made by such techniques as pultrusion, tube rolling, tape wrapping or filament winding. When the composite shaft is tubular and is manufactured by a filament winding process, it is preferred that the winding

angle is less than 45° with respect to the tube axis.

The inner member and annular outer member of the end fitting assembly may be made of any suitable material and may be made of different materials to each other. The inner member may be secured to the annular outer member by mechanical means such as bolts, or dowels, continuous or spot welding, or a screw thread or any combination of these. The frusto-conical surfaces of the inner member and annular outer member may be of the same or different shape.

The outer member may also define an outward facing frusto-conical surface, coaxial with the inward facing frusto-conical surface, and these two surfaces may be of the same cone half-angle. However if the half-angle of the outward facing surface is greater than that of the inward facing surface, so the intervening portion of the outer member tapers, the resulting joint may be stronger than joints made with outer members which have both frusto-conical surfaces substantially parallel.

The joint is assembled with the composite shaft in the green state. By green state it is meant that the fibre-reinforced plastic material may be malleable, deformable, pliable, or compliant and that these properties can be removed or altered by further treatment. When the composite shaft comprises a fibre reinforced thermosetting plastic the further treatment may be any suitable curing process. When the plastic is a thermoplastic such as polyetheretherketone (PEEK), the green state may be at elevated temperatures and further treatment may comprise cooling of the thermoplastic.

In general the area of the bonded surfaces of a joint may be related to the strength of the joint; the larger the

bond area for a given bond length the greater the strength of the joint. As the cone half-angle of the frusto-conical bonded surface is increased then the area of the bonded surfaces will also increase and thus the strength of the joint will increase. The strength of the joint may be further improved by increasing the bond length. By altering the angles of the frusto-conical surfaces and the length of the adhesively bonded surfaces various joints can be prepared to a range of desired strengths. When filament wound composite shafts are used in the manufacture of a joint it is preferable that the length and the cone half-angles of the bonded frusto-conical surfaces are such that the reinforcing filaments or fibres of the composite shaft are not significantly distorted or damaged during assembly of the joint. Preferably the cone half-angles of the frusto-conical end-portion and frusto-conical surfaces to be adhesively bonded are less than 45° and more preferably less than 25°. It is possible to accommodate long bond lengths whilst maintaining the minimum of distortion of the reinforcing filaments or fibres of the composite tube by the use of additional features such as regions of the composite tube which are cylindrical and co-axial or substantially co-axial with the axis of the tube, adjacent to the frusto-conical end-portion and located within the end-fitting.

Once assembled and cured the joint is strong and durable. When adhesive bonding is used the combination of mechanical interlocking, which is produced between the frusto-conical end-portion and the end-fitting assembly, and adhesive bonding of the frusto-conical end-portion to the end-fitting assembly produces a stronger more durable joint.

The joint is suitable for applications where a joint

is required to be strong and durable under torsional and/or axial loads, for example in the manufacture of composite drillstrings for use in oil exploration, when both the composite shaft and the end-fitting assembly would be tubular. The joint may also be suitable for the production of well casings as used in oil exploration.

The joint may be used in such applications as driveshafts, bracing members or any application where a fibre reinforced composite rod requires joining to rods or devices of material other than fibre reinforced composite and in such cases the shaft and the inner member may be non-tubular.

It is a feature of the method of manufacture of the joint, that the annular outer member does not require splitting. If splitting were required this would necessitate additional fixtures for securing the split outer member with a consequential increase in the weight of the joint. It is also a cheaper method than previously suggested processes, as it reduces the precision with which mating components need to be produced to obtain a good quality adhesive bond, and eliminates the need to machine the composite shaft.

The invention will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a longitudinal section of a joint comprising a tubular composite shaft and a tubular end-fitting assembly;

Figure 2 shows a longitudinal section of the components of the joint of Figure 1 before assembly of the joint;

Figure 3 shows a longitudinal view, part in elevation and part in section, of a composite drillstring joint comprising a tubular composite shaft and a tubular end-fitting assembly and;

Figure 4 shows a longitudinal section of a joint comprising a tubular composite shaft and a non-tubular end-fitting assembly.

Referring to Figure 1 there is shown a joint 10 which comprises a tubular shaft 11 of fibre-reinforced plastic material with a frusto-conical end-portion 13, and a tubular end-fitting assembly 14 which comprises an annular inner member 15 and an annular one-piece outer member 16 secured to each other by bolts 17 (only two are shown) and weld 19. There is an adhesive fillet 12 between the shaft 11 and the open end of the member 15. The frusto-conical end-portion 13 is in contact with, and supported and retained within the end-fitting assembly 14 by, frusto-conical surfaces 20 and 21 of the annular inner member 15 and annular outer member 16 respectively. The surface 22 of the bore of the annular inner member 15 is of the same diameter as the bore 23 of the tubular composite shaft 11.

Referring to Figure 2 there are shown the components of the joint 10 before assembly and curing. The components are assembled in the following manner to make the composite joint of Figure 1. A composite tube 30 in its green state with bore 23 of substantially uniform diameter and cross-section throughout its length is passed through the bore 32 of the annular outer member 16 such that the end 35 of the composite tube 30 extends beyond the end of the annular outer member 16. The frusto-conical region 34 of the annular inner member 15 is then inserted into the bore

30 at end 33 of the composite tube 30 with force in direction A, so deforming the composite tube 30 to form the frusto-conical end-portion 13 (shown in Figure 1). The inner member 15 is inserted until the end 33 of the composite tube abuts a surface 35 of the inner member 15. The annular outer member 16 is then forced back along the composite tube 30 in direction B until an end face 36 of the annular outer member 16 contacts a surface 37 of the annular inner member 15; at this point the frusto-conical surface 21 of the annular outer member 16 is in intimate contact with the outer surface of the frusto-conical end-portion 13 (shown in Figure 1). The annular outer member 16 is secured to the annular inner member 15 by means of the bolts 17 inserted through the apertures 18, and by the weld 19. The secured end-fitting assembly is then treated to cure the composite tube 30.

Referring to Figure 3 there is shown a composite drillstring joint 40 which comprises, a fibre-reinforced plastic tubular shaft 41 with internal diameter 137mm and a wall thickness of 9.2mm with a frusto-conical end-portion 42 of axial length 200mm and adjacent cylindrical co-axial end-portion 43 of axial length 100mm, and a tubular end-fitting assembly 44 which comprises an annular inner member 45 and an annular one-piece outer member 46 secured to each other by bolts 47 (only four are shown). The frusto-conical end-portion 42 is in mating contact with, and is supported and retained within the end-fitting assembly 44 by, frusto-conical surfaces 47 and 48 of the annular inner member 45 and the annular outer member 46 respectively. The annular inner member 45 and the annular outer member 46 have cylindrical co-axial surfaces 49 and 50 respectively which are in mating contact with the flat end-portion 43 of the fibre-reinforced plastic tubular shaft 41. All of the mating surfaces are adhesively bonded. The outer surface 51 of the annular outer member

46 is also of frusto-conical form. The cone half-angles a, b and c, with respect to the axis of the joint, of the frusto-conical surfaces are such that angle b and c are equal and such that the tapering portions 52 and 53 of the outer annular member 46 and of the annular inner member 45 respectively are of the same wedge angle (i.e. a-b=c), and also are of the same axial length.

It will be appreciated that the tapering portions of the outer annular member and of the annular inner member may have differing dimensions depending on the application and materials used.

Referring to Figure 4 there is shown a joint 60 which comprises a tubular shaft 61 of fibre-reinforced plastic material with a frusto-conical end-portion 62 and a non-tubular end-fitting assembly 63 which comprises an inner member 64 with outward facing frusto-conical surface 65 and an annular one-piece outer member 66 with inward facing frusto-conical surface 67 secured to each other via bolts 68 (only two are shown). The frusto-conical end-portion 62 is in contact with and supported and retained within the end-fitting assembly 63 by frusto-conical surface 65 and 67 of the inner member 64 and annular outer member 66 respectively. Both frusto-conical surfaces 65 and 67 are adhesively bonded to the frusto-conical end-portion 62.

Claims

1. A joint which comprises a shaft of a fibre reinforced plastic material with a frusto-conical tubular end-portion, with cone half-angle of less than 45° with respect to the joint axis, axially interlocked with an end-fitting assembly which comprises an inner member with an outward facing frusto-conical surface and an annular one-piece outer member with an inward facing frusto-conical surface, the said frusto-conical surfaces of the inner and the outer members mating with inner and outer frusto-conical surfaces of the frusto-conical end portion of the shaft, and the inner and outer members being secured to each other.

2. A joint as claimed in claim 1 wherein all the mating frusto-conical surfaces are adhesively bonded.

3. A joint as claimed in claim 2 wherein all the mating surfaces am adhesively bonded.

4. A joint as claimed in claim 2 or claim 3 wherein the adhesive forms a fillet.

5. A joint as claimed in any one of claims 2 to 4 wherein the adhesive is an epoxy or a phenolic nitrile adhesive.

6. A joint as claimed in claim 1 wherein the frusto-conical tubular end-portion also comprises an integral adhesive.

7. A joint as claimed in any one of the preceding claims wherein the wall of the frusto-conical tubular end portion is wedge-shaped in section.

8. A joint as claimed in any one of the preceding claims wherein the fibre reinforced plastic material is a filament wound plastic material.

9. A joint as claimed in any one of the preceding claims wherein the fibre reinforced plastic material is a fibre reinforced epoxy resin.

10. A joint as claimed in any one of the preceding claims wherein the outer member also defines an outward facing frusto-conical surface having a cone half-angle which is equal to or greater than that of the inward facing frusto-conical surface of the outer member.

11. A joint as claimed in any one of the preceding claims wherein the cone half-angles of the frusto-conical surfaces are less than 45°.

12. A joint as claimed in claim 11 wherein the cone half-angles are less than 25°.

13. A method of manufacture of a joint comprising inserting an inner member defining an outward facing frusto-conical surface into an end of a shaft of a fibre reinforced plastic material in its green state, such that a frusto-conical tubular end portion is formed in the shaft, pushing an annular outer member defining an inward facing frusto-conical surface along the outside of the shaft towards the frusto-conical end portion until its frusto-conical surface mates with the external surface of the frusto-conical end portion, securing the annular outer member to the inner member to form an end-fitting assembly, and treating the end-fitting assembly to convert the composite shaft from its green state to its cured state.

14. A method as claimed in claim 13 including the step of applying adhesive to the frusto-conical surfaces of the inner and outer members.

15. A method as claimed in claim 13 or claim 14 including the step of applying adhesive to that part of the end of the shaft which forms the frusto-conical tubular end portion.

16. A method as claimed in claim 13 wherein the fibre reinforced plastic material also comprises an integral adhesive.

17. A method as claimed in any one of claims 14 to 16 wherein the adhesive is caused to spill out of the joint or assembly to form a fillet.

18. A joint substantially as hereinbefore described with reference to, and as shown in, Figure 1, Figure 3, or Figure 4.

19. A method of manufacture of a joint substantially as hereinbefore described with reference to, and as shown in, Figures 1 and 2, or Figure 3, or Figure 4.

**Patents Act 1977**
**Examiner's report to the Comptroller under Section 17 (The Search Report)**

Application number
GB 9217004.2

**Relevant Technical fields**

(i) UK Cl (Edition K ) F2G (G24E, G24Z, G33, G18, GRX); F2U

5 F16L, F16C 3/02

(ii) Int Cl (Edition )

Search Examiner
B J PROCTOR

**Databases** (see over)

(i) UK Patent Office

(ii)

Date of Search
7 OCTOBER 1992

Documents considered relevant following a search in respect of claims 1 TO 19

| Category (see over) | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| X | GB 2112689 A (BRISTOL) | 1 at least |
| X | GB 2051303 A (CALANENE) | 1 at least |
| X | GB 1405139 | 1 at least |
| X | GB 718264 (WARD) eg Figure 3 | 1, 2 |
| X | GB 291674 (PLANQUE) eg Figures 1-6 | 1 |
| X | GB 254619 (SCHOLES) eg Figure 3 | 1 |
| X | GB 248130 (HEATH) eg Figures 1-4 | 1 |
| X | WO 88/01887 A1 (ABIOMED C INC) eg Figure 1 | 1 |

| Category | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| | | |

## Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

**Databases:** The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

Published 1993 at The Patent Office, Concept House, Cardiff Road, Newport, Gwent NP9 1RH. Further copies may be obtained from Sales Branch, Unit 6, Nine Mile Point, Cwmfelinfach, Cross Keys, Newport, NP1 7HZ. Printed by Multiplex techniques ltd, St Mary Cray, Kent.